

Research Article

Effectiveness of Flipped Classroom Versus Traditional Lecture in Pharmacology Among Undergraduate Medical Students: A Quasi-Experimental Study

Sathiyathan Thirumurugan ^{1*}, Gajanan Kulkarni ², Prabhmeet Kaur ³ and Saranya Saravanajothi ³

¹Department of Pharmacology, ESIC Medical college & Hospital, Kalaburagi, Affiliated to RGUHS Bengaluru, Karnataka - 585105, India.

²Department of Pharmacology, Symbiosis medical college for Women, Pune, Affiliated to Symbiosis international University, Pune - 412115, India.

³Department of Pharmacology, Bidar Institute of Medical Sciences, Bidar, Affiliated to RGUHS Bengaluru, Karnataka - 585401, India.

*Corresponding author: drsathiyathan10@gmail.com

Article Info

Keywords: Active learning, Flipped classroom, Medical education, Student perception, Traditional lecture.

Received: 02.07.2026;

Accepted: 21.07.2026;

Published: 26.07.2026



© 2026 by the author's. The terms and conditions of the Creative Commons Attribution (CC BY) license apply to this open access article.

Abstract

Background: Traditional lecture-based teaching in medical education is predominantly teacher-centred and often limits active student participation. Learner-centred approaches such as the flipped classroom have gained attention for enhancing engagement and promoting deeper learning.

Aim: To compare the effectiveness of flipped classroom and traditional lecture methods on academic performance and to assess student perceptions among second-year undergraduate medical students.

Materials and Methods: This quasi-experimental, within-subject comparative study was conducted among 130 second-year MBBS students at a tertiary care teaching hospital. Students attended a traditional lecture session on skeletal muscle relaxants and a flipped classroom session on local anaesthetics. Pre-class materials were provided for the flipped session. Post-tests consisting of multiple-choice questions were administered after each session. Student perceptions were collected using a structured questionnaire. As data were not normally distributed, the Wilcoxon signed-rank test was used for comparison of scores, and Chi-square test was applied for categorical variables. A p-value <0.05 was considered statistically significant.

Results: The flipped classroom method demonstrated significantly higher student engagement, interest, and improved comprehension and logical reasoning compared to traditional lectures (p<0.05). Student involvement and perceived understanding were also significantly higher in the flipped classroom group (p=0.006). However, no significant difference was observed in ease of understanding and overall enjoyment between the two methods.

Conclusion: The flipped classroom is an effective teaching-learning strategy that enhances student engagement and higher-order cognitive skills. A blended approach incorporating both flipped classroom and traditional lectures may provide optimal learning outcomes in medical education.

1. Introduction

Medical education in India has traditionally relied on didactic lectures as the primary mode of instruction, particularly during the early years of undergraduate training [1]. However, this approach is largely teacher-centred and limits active student participation, critical thinking, and meaningful interaction [2].

With the implementation of Competency-Based Medical Education (CBME), there has been a paradigm shift toward learner-centred approaches that promote self-directed learning, critical thinking, and application of knowledge in clinical contexts. Teaching-learning methods such as case-based learning (CBL), problem-based learning (PBL), self-directed learning (SDL), and flipped classroom have gained increasing importance [3–5]. In order to increase student engagement and improve learning outcomes, innovative methods for teaching and learning including concept mapping, flipped classroom approaches, Case-Based Learning (CBL), Problem-Based Learning (PBL), and Self-Directed Learning (SDL) are being used more and more globally [4, 5].

One type of blended learning that contradicts the conventional teaching style is the flipped classroom [6]. By using pre-recorded lectures, reading materials, or other digital resources to introduce students to fundamental concepts prior to class, this method frees up class time for active learning activities like discussions, problem-solving, and idea application [6–8]. Through direct participation, this paradigm fosters deeper knowledge while allowing students to learn at their own speed [9].

The flipped classroom helps students learn these fundamental ideas outside of the classroom, in contrast to typical lectures where lower-order cognitive processes like remembering and understanding take place during class [10, 11]. According to Bloom's revised taxonomy [10, 11], higher-order cognitive processes including application, analysis, evaluation, and creativity might also be used during class time. Students' critical thinking, communication, and cooperative learning skills are all supported by this shift [12].

When compared to traditional lecture-based instruction, a number of studies have shown that the flipped classroom improves student motivation, engagement, and academic performance [13, 14]. Additionally, it promotes self-directed learning and a good learning environment [3]. Nevertheless, there is variation in its application and efficacy across various educational contexts, despite its growing popularity [9, 13].

It has been demonstrated that active learning techniques, such as flipped classroom models, greatly enhance student performance and knowledge retention when compared to conventional lecture-based approaches [3, 14]. Active learning improves exam performance and lowers failure rates in undergraduate scientific education, according to a meta-analysis by Freeman et al. [14]. Similarly, Prober and Heath noted that by promoting student participation both before and during class, the flipped classroom fosters greater comprehension and long-term memory of information [15].

An essential link between the fundamental sciences and clinical practice is pharmacology, a core subject in the second year of medical school [16]. In order to ensure that students not only get knowledge but also develop the capacity to apply pharmacological concepts in clinical contexts, effective teaching approaches in this topic are crucial [17].

2. Methods

Study Design and Setting

This was a prospective, quasi-experimental, within-subject comparative study conducted at the Bidar Institute of Medical Sciences, Bidar, a tertiary care teaching hospital in Karnataka, India.

Study Population

The study included second-year undergraduate medical students enrolled at the institution.

Inclusion and Exclusion Criteria

All second-year undergraduate medical students who provided verbal informed consent were included in the study. Students who did not consent to participate were excluded.

Sample Size

A total of 130 students were included in the study through sequential enrolment.

Ethical Considerations

Institutional Ethics Committee approval was obtained prior to the commencement of the study (IEC Approval No. 271/BRIMS/IEC/2025). Verbal informed consent was obtained from all participants after explaining the purpose and procedure of the study.

Study Procedure

The planned teaching sessions, which included both standard lecture and flipped classroom approaches, were announced to the students one week in advance.

Two different pharmacology topics of comparable curricular weightage and conceptual complexity — Skeletal Muscle Relaxants and Local Anaesthetics — were selected for the traditional lecture and flipped classroom sessions, respectively. Both topics had not been previously taught to the study cohort, and their comparability in terms of difficulty and number of sub-concepts was independently confirmed by two senior faculty members of the department, in order to minimize the potential influence of topic difficulty on the comparison of learning outcomes.

Traditional Lecture

A 30-minute didactic lesson on "Skeletal Muscle Relaxants" was attended by every student. A post-test with multiple-choice questions (MCQs) was given after the session. Using a structured Google Form, students also shared their opinions about the teaching approach.

Flipped classroom session

Students were given access to pre-recorded lecture videos and handout materials on the subject of "Local Anaesthetics" before the flipped classroom session. Reminders were sent out the day before the class, and students were urged to review these materials.

Students participated in problem-based learning exercises in small groups during the class period. Each group used a group leader to present their findings after discussing the given problem. An interactive conversation led by the teachers ensued.

A structured, self-administered Google Form was used to offer a post-test with ten multiple-choice questions (one mark each) at the conclusion of the session. Knowledge, comprehension, application, and problem-solving skills were evaluated by the questions. Students' opinions of the flipped classroom approach and their level of confidence in their comprehension of the subject were also gathered. All participants were exposed to both teaching methods, thereby minimizing inter-individual variability.

Data Collection

Over the course of one month (October 2025), data were collected.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using Jamovi version 2.7.15 and IBM SPSS Statistics version 20.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD), while ordinal data from Likert scale responses were summarized as median with interquartile range (IQR).

The normality of data distribution was assessed using the Shapiro–Wilk test. As the data were not normally distributed ($p < 0.05$), the Wilcoxon signed-rank test was used to compare post-test scores between the two teaching methods. The Chi-square test was used to compare categorical variables. A p -value < 0.05 was considered statistically significant.

3. Results

A total of 130 students participated in the study. All students attended both teaching sessions and completed the post-tests and feedback questionnaires.

The mean post-test score following the flipped classroom session was 7.42 ± 1.69 , compared to 7.41 ± 2.18 in the traditional lecture session. The difference in scores between the two teaching methods was not statistically significant (Wilcoxon signed-rank test, $p = 0.553$). This indicates that both teaching methods were comparable in terms of immediate academic performance.

Table 1: Wilcoxon signed-rank test to compare the two teaching methods

		N	Mean $\pm$ SD	Median (IQR)	Range	Wilcoxon Signed-rank test	P value
1) Method is easy to understand	Flipped	130	3.63 $\pm$ 0.899	4 (3,4)	1 to 5	7627	0.136
	Traditional	130	3.51 $\pm$ 0.856	4 (3,4)	1 to 5		
2) The method promotes the interest for the topic.	Flipped	130	3.57 $\pm$ 0.914	4 (3,4)	1 to 5	7191	0.028
	Traditional	130	3.3 $\pm$ 1.024	3 (3,4)	1 to 5		
3) Promotes meaningful learning.	Flipped	130	3.62 $\pm$ 0.918	4 (3,4)	1 to 5	7436	0.072
	Traditional	130	3.45 $\pm$ 0.873	4 (3,4)	1 to 5		
4) It helped in understanding the topic & promote rational thinking.	Flipped	130	3.67 $\pm$ 0.927	4 (3,4)	1 to 5	6775	0.003
	Traditional	130	3.33 $\pm$ 0.96	3 (3,4)	1 to 5		
5) It is an aid for studying, organizing, and summarizing information learned through activities.	Flipped	130	3.65 $\pm$ 0.946	4 (3,4)	1 to 5	8070	0.503
	Traditional	130	3.6 $\pm$ 0.928	4 (3,4)	1 to 5		
6) I developed a deeper understanding of the individual topic.	Flipped	130	3.42 $\pm$ 1.011	3.5 (3,4)	1 to 5	7341	0.055
	Traditional	130	3.17 $\pm$ 1.005	3 (3,4)	1 to 5		
7) I enjoyed the whole process of the Teaching learning methods.	Flipped	130	3.52 $\pm$ 0.958	4 (3,4)	1 to 5	7459	0.082
	Traditional	130	3.35 $\pm$ 0.897	3 (3,4)	1 to 5		
8) Learning via this learning method takes more time.	Flipped	130	3.18 $\pm$ 1.045	3 (2,4)	1 to 5	7767	0.239
	Traditional	130	3.32 $\pm$ 1.006	3 (3,4)	1 to 5		
9) Increased my level of involvement and improved my understanding.	Flipped	130	3.59 $\pm$ 0.904	4 (3,4)	1 to 5	6879	0.006
	Traditional	130	3.28 $\pm$ 0.948	3 (3,4)	1 to 5		
10) Learning via Lectures should continue to be a part of the MBBS undergraduate curriculum.	Flipped	130	3.7 $\pm$ 0.929	4 (3,4)	1 to 5	8344	0.853
	Traditional	130	3.65 $\pm$ 0.97	4 (3,4)	1 to 5		

The flipped classroom method demonstrated statistically significant improvement in promoting student interest ($p = 0.028$), enhancing

comprehension and logical reasoning ($p = 0.003$), and increasing student involvement ($p = 0.006$) compared to the traditional lecture method as shown in Table 1.

Similarly, the distribution of categorical responses between the flipped classroom and traditional lecture groups was compared using the Chi-square test.

A statistically significant difference was observed only for the statement “increased my level of involvement and improved my understanding” ($\chi^2 = 10.302$, $p = 0.036$), with a higher proportion of agreement in the flipped classroom group. For other items, including enjoyment of the learning process ($p = 0.140$), perception of time required for traditional learning ($p = 0.749$), and continuation of lectures in the curriculum ($p = 0.862$), no statistically significant differences were observed between the two groups.

Overall, most response distributions were comparable between the two teaching methods, with the flipped classroom demonstrating a significant advantage only in terms of student involvement and perceived understanding as shown in Table 2.

Table 2: Chi square test to compare the Categorical Entities

	Categories	N	Group		Chi square	P value
			Flipped (N (%))	Traditional (N (%))		
1) Method is easy to understand	Strongly disagree	9	4 (3.1)	5 (3.8)	6.106	0.191
	Disagree	18	11 (8.5)	7 (5.4)		
	Neutral	72	28 (21.5)	44 (33.8)		
	Agree	138	73 (56.2)	65 (50)		
	Strongly agree	23	14 (10.8)	9 (6.9)		
2) The method promotes the interest for the topic.	Strongly disagree	11	3 (2.3)	8 (6.2)	6.149	0.188
	Disagree	32	14 (10.8)	18 (13.8)		
	Neutral	77	34 (26.2)	43 (33.1)		
	Agree	113	64 (49.2)	49 (37.7)		
	Strongly agree	27	15 (11.5)	12 (9.2)		
3) Promotes meaningful learning.	Strongly disagree	8	5 (3.8)	3 (2.3)	5.192	0.268
	Disagree	21	8 (6.2)	13 (10)		
	Neutral	82	35 (26.9)	47 (36.2)		
	Agree	122	66 (50.8)	56 (43.1)		
	Strongly agree	27	16 (12.3)	11 (8.5)		
4) It helped in understanding the topic, promote rational thinking.	Strongly disagree	10	4 (3.1)	6 (4.6)	9.26	0.055
	Disagree	25	8 (6.2)	17 (13.1)		
	Neutral	81	36 (27.7)	45 (34.6)		
	Agree	113	61 (46.9)	52 (40)		
	Strongly agree	31	21 (16.2)	10 (7.7)		
5) It is an aid for studying, organizing, and summarizing information learned through activities.	Strongly disagree	8	4 (3.1)	4 (3.1)	2.019	0.732
	Disagree	20	11 (8.5)	9 (6.9)		
	Neutral	72	31 (23.8)	41 (31.5)		
	Agree	121	64 (49.2)	57 (43.8)		
	Strongly agree	39	20 (15.4)	19 (14.6)		
6) I developed a deeper understanding of the individual topic.	Strongly disagree	16	6 (4.6)	10 (7.7)	5.747	0.219
	Disagree	34	15 (11.5)	19 (14.6)		
	Neutral	91	44 (33.8)	47 (36.2)		
	Agree	95	48 (36.9)	47 (36.2)		
	Strongly agree	24	17 (13.1)	7 (5.4)		
7) I enjoyed the whole process of the Teaching learning methods.	Strongly disagree	9	4 (3.1)	5 (3.8)	6.927	0.14
	Disagree	27	15 (11.5)	12 (9.2)		
	Neutral	91	36 (27.7)	55 (42.3)		
	Agree	107	59 (45.4)	48 (36.9)		
	Strongly agree	26	16 (12.3)	10 (7.7)		
8) Learning via this learning takes more time.	Strongly disagree	13	7 (5.4)	6 (4.6)	1.929	0.749
	Disagree	50	29 (22.3)	21 (16.2)		
	Neutral	79	39 (30)	40 (30.8)		
	Agree	95	44 (33.8)	51 (39.2)		
	Strongly agree	23	11 (8.5)	12 (9.2)		
9) Increased my level of involvement and improved my understanding.	Strongly disagree	11	5 (3.8)	6 (4.6)	10.302	0.036
	Disagree	27	7 (5.4)	20 (15.4)		
	Neutral	82	39 (30)	43 (33.1)		
	Agree	118	64 (49.2)	54 (41.5)		
	Strongly agree	22	15 (11.5)	7 (5.4)		
10) Learning via Lectures should continue to be a part of the MBBS undergraduate curriculum.	Strongly disagree	8	3 (2.3)	5 (3.8)	1.296	0.862
	Disagree	15	7 (5.4)	8 (6.2)		
	Neutral	79	42 (32.3)	37 (28.5)		
	Agree	109	52 (40)	57 (43.8)		
	Strongly agree	49	26 (20)	23 (17.7)		

These findings indicate that the flipped classroom approach is more effective in promoting higher-order cognitive skills and active student participation, although both methods were comparable in basic understanding and overall learning experience. This difference in response distribution is illustrated in Figure 1.

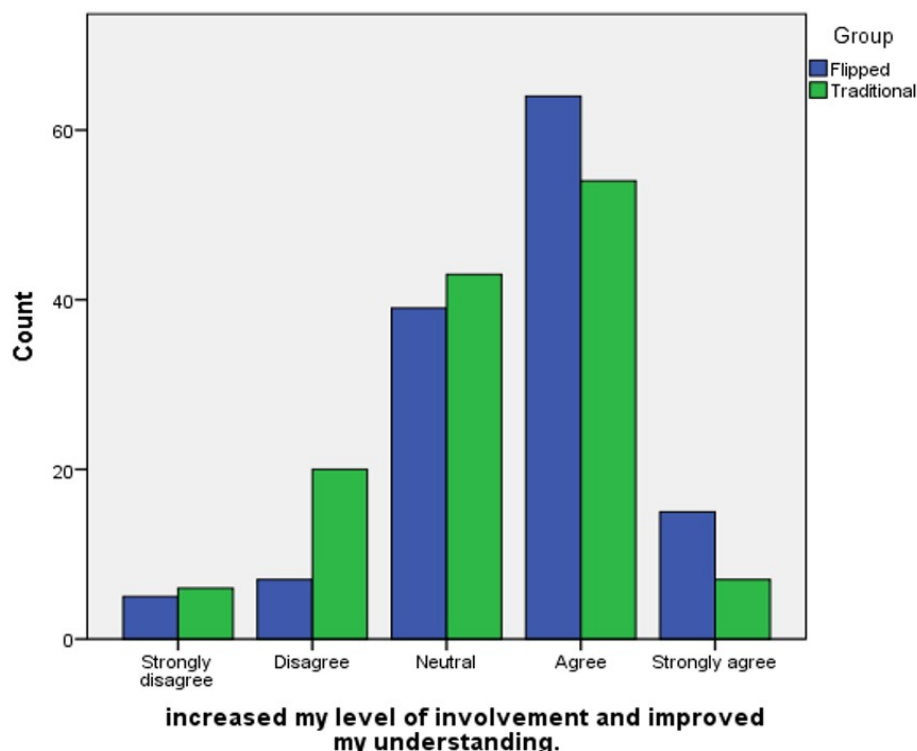


Figure 1: Comparison between Flipped and Traditional Teaching for student involvement and improved understanding

As shown in Figure 2, students exposed to the flipped classroom approach also showed a statistically significant improvement in comprehension and logical reasoning ($p = 0.003$).

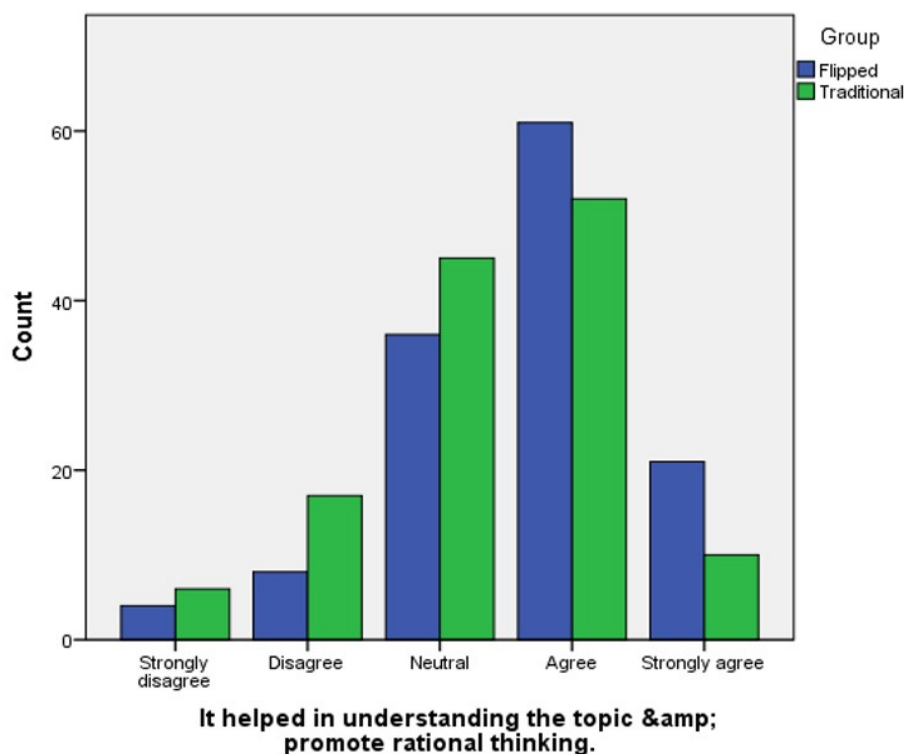


Figure 2: Comparison of traditional and Flipped teaching for comprehension and logical reasoning

It was also observed that the flipped classroom approach considerably increased students' interest in the subject when compared to

traditional teaching ($p = 0.028$) as depicted in Figure 3.

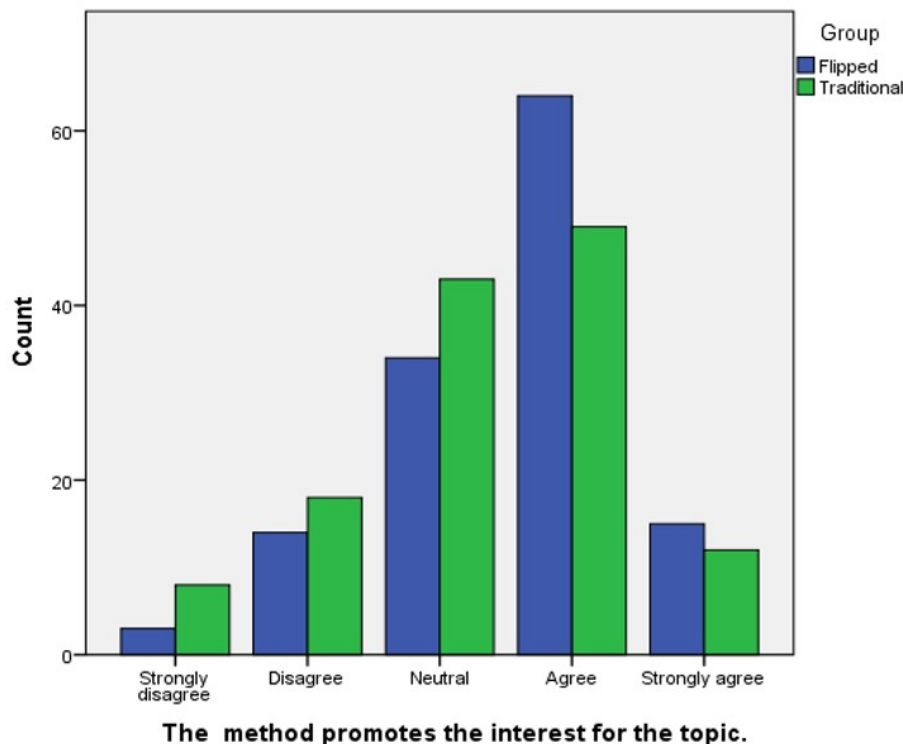


Figure 3: Comparison of traditional and Flipped Teaching for increased students' interest

4. Discussion

The present study compared the effectiveness of flipped classroom and traditional lecture methods in improving student engagement, interest, and higher-order learning outcomes among undergraduate medical students. The findings demonstrated that the flipped classroom approach was significantly more effective in enhancing student involvement, comprehension, and logical reasoning.

The flipped classroom approach aligns well with the principles of Competency-Based Medical Education (CBME), as it promotes self-directed learning, critical thinking, and application of knowledge. It also supports higher domains of learning as described in Bloom's taxonomy, which are essential for developing clinical reasoning and decision-making skills in medical students.

Although mean scores were slightly higher in the flipped classroom group, these differences were not statistically significant. When compared to traditional lectures, the flipped classroom approach greatly increased student participation and comprehension in the current study. This result is in line with earlier research that concluded that by using classroom time for discussion and application-based learning, flipped learning increases conceptual knowledge and encourages active involvement [1, 14]. In health professions education, active learning techniques have been demonstrated to enhance student performance and lower failure rates [14].

Additionally, the study showed that implementing the flipped classroom paradigm significantly increased students' interest in the subject. This could be explained by the method's interactive and student-centred approach, which promotes participation through preparation before class and problem-solving during class. Gilboy et al. noticed that flipped classroom approaches increase student motivation and involvement in learning, which is consistent with similar findings [8]. Chen et al. also noted that students find flipped classrooms to be more interesting and captivating than regular lectures [13].

These findings are consistent with more recent evidence. A 2023 Campbell systematic review by Naing et al. [18], pooling data from 45 studies involving 8,426 undergraduate health-professional students, found that flipped classroom instruction was generally associated with improved or comparable academic performance relative to traditional teaching, alongside consistently higher course satisfaction. Similarly, a 2025 systematic review and meta-analysis by Spaic et al. [19], focusing specifically on post-pandemic medical education literature, reported that flipped classroom instruction was associated with improved knowledge outcomes across several subfields of medical education, though the magnitude of benefit varied by discipline and outcome measure — a pattern mirrored in our finding of comparable post-test scores but significantly higher engagement in the flipped classroom group. A 2024 meta-analysis by Shi et al. [20], restricted to clinical medical education, similarly found the flipped classroom to be superior to traditional teaching for skill- and competency-based outcomes, but with more modest and inconsistent effects on knowledge test scores alone, further supporting our observation that the primary benefit of the flipped classroom in the present study was in engagement and higher-order reasoning rather than immediate post-test performance.

Even though the flipped classroom showed benefits in some areas, there were no statistically significant differences found between the two teaching approaches in terms of factors like comprehension ease, meaningful learning, content organization, and general enjoyment of the learning process. These results imply that traditional lectures are still useful for imparting fundamental knowledge, even though flipped learning improves engagement and higher-order thinking. Similar findings have been documented in earlier research, where it was discovered that both teaching strategies were successful but had distinct advantages [21–23].

These results were further supported by the Chi-square analysis, which revealed similar answer distributions for other parameters but only

a significant difference in terms of enhanced student involvement and comprehension. This suggests that encouraging active participation rather than totally substituting conventional approaches is the main benefit of flipped learning.

The flipped classroom strategy has certain drawbacks despite its benefits. Students must prepare ahead of time, which could add to their burden and not always be possible for everyone in the class. The efficiency of this approach may also be impacted by access to digital resources and technological infrastructure. Previous studies assessing the deployment of flipped classrooms have also emphasized these difficulties.

Flipped classroom approaches are especially beneficial for pharmacology, a discipline that requires both conceptual clarity and clinical application. Medical students need to be able to apply their theoretical knowledge to clinical situations, and active learning strategies can help them make this transition [10, 16].

Overall, the results of this study suggest that the flipped classroom is a useful supplement to conventional teaching techniques. For undergraduate medical students, a mixed strategy that incorporates both approaches may offer the best learning experience rather than totally replacing lecture.

5. Conclusion

The present study demonstrates that the flipped classroom is an effective teaching-learning strategy that enhances student engagement, interest, and higher-order cognitive skills among undergraduate medical students. However, both flipped classroom and traditional lecture methods were comparable in delivering foundational knowledge. Therefore, a blended approach incorporating both strategies may provide optimal learning outcomes in pharmacology education.

Limitation

There are some limitations to the current investigation. First, the study's small sample size and single institution setting may have an impact on how broadly applicable the results are. Second, long-term knowledge retention was not evaluated; only immediate perceptions and short-term academic achievement were. Third, students had to prepare ahead of time for the flipped classroom method, which might have affected their replies and degree of participation. Lastly, the study may not represent results from other areas or fields because it was restricted to certain pharmacological themes.

Article Information

Acknowledgements: The authors would like to thank MBBS students' of 2022 batch for their active participation and honest opinion. We would also like to thank Dr. Syeda Ayesha Nishat, Dr. Amulya Shetkar, Dr. Azra Shahwar for their contribution towards this study.

Author Contributions: S.T. - Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Supervision; G.K. - Writing – review & editing, Supervision; P.K. - Data curation, Writing – review & editing; S.S. - Data curation, Writing – review & editing.

Funding / Financial Support: No funding has been received from any organization or individual for this research.

Conflict of Interest (Competing Interests): The authors declare no competing interests.

Ethical Approval: Institutional Ethics Committee approval was obtained prior to the commencement of the study (IEC Approval No. 271/BRIMS/IEC/2025).

Informed Consent: Verbal informed consent was obtained from all participants after explaining the purpose and procedure of the study.

Data Availability Statement: Data available on reasonable request.

Clinical Trial Registration: Not Applicable.

Reporting Guidelines Statement: Not Applicable.

Disclaimer (Artificial Intelligence): The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.), and text-to-image generators have been used during writing or editing of manuscripts.

References

- [1] J. E. McLaughlin, M. T. Roth, D. M. Glatt, N. Gharkholonarehe, C. A. Davidson, L. M. Griffin, Esserman. D. A., and R. J. Mumper. The flipped classroom: a course redesign to foster learning and engagement in a health professions school. *Acad Med*, 89(2):236–243, 2014.
- [2] K. S. Chen, L. Monrouxe, Y. H. Lu, C. C. Jenq, Y. J. Chang, Y. C. Chang, and P. Y. Chai. Academic outcomes of flipped classroom learning: a meta-analysis. *Med Educ*, 52(9):910–924, 2018.
- [3] M. Prince. Does active learning work? A review of the research. *J Eng Educ*, 93(3):223–231, 2004.
- [4] R. M. Harden and J. M. Laidlaw. *Essential skills for a medical teacher: an introduction to teaching and learning in medicine*. Elsevier, London, 2nd edition, 2017.
- [5] M. J. Lage, G. J. Platt, and M. Treglia. Inverting the classroom: a gateway to creating an inclusive learning environment. *J Econ Educ*, 31(1):30–43, 2000.

- [6] J. Bergmann and A. Sams. *Flip your classroom: reach every student in every class every day*. International Society for Technology in Education, Washington DC, 2012.
- [7] J. L. Bishop and M. A. Verleger. The flipped classroom: a survey of the research. In *Proceedings of the 120th ASEE Annual Conference & Exposition*, 2013.
- [8] M. B. Gilboy, S. Heinerichs, and G. Pazzaglia. Enhancing student engagement using the flipped classroom. *J Nutr Educ Behav*, 47(1): 109–114, 2015.
- [9] J. O’Flaherty and C. Phillips. The use of flipped classrooms in higher education: A scoping review. *Internet High Educ.*, 25:85–95, 2015.
- [10] L. W. Anderson and D. R. Krathwohl. *A taxonomy for learning, teaching, and assessing: a revision of Bloom’s taxonomy of educational objectives*. Longman, New York, 2001.
- [11] B. S. Bloom. *Taxonomy of educational objectives: the classification of educational goals. Handbook I: Cognitive domain*. David McKay Company, New York, 1956.
- [12] J. Michael. Where’s the evidence that active learning works? *Adv Physiol Educ*, 30(4):159–167, 2006.
- [13] F. Chen, A. M. Lui, and S. M. Martinelli. A systematic review of the effectiveness of flipped classrooms in medical education. *Med Educ*, 51(6):585–597, 2017.
- [14] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci USA*, 111(23):8410–8415, 2014.
- [15] C. G. Prober and C. Heath. Lecture halls without lectures—a proposal for medical education. *N Engl J Med*, 366(18):1657–1659, 2012.
- [16] K. D. Tripathi. *Essentials of Medical Pharmacology*. Jaypee Brothers Medical Publishers, New Delhi, 8th edition, 2019.
- [17] A. M. Persky and G. M. Pollack. Transforming a large-class lecture course to a smaller-group interactive course: a flipped classroom approach. *Am J Pharm Educ*, 74(9):170, 2010.
- [18] C. Naing, M. A. Whittaker, H. H. Aung, D. K. Chellappan, and A. Riegelman. The effects of flipped classrooms to improve learning outcomes in undergraduate health professional education: a systematic review. *Campbell Syst Rev*, 19(3):e1339, 2023.
- [19] D. Spaic, Z. Bukumiric, N. Rajovic, K. Markovic, M. Savic, J. Milin-Lazovic, N. Grubor, N. Milic, D. Stanisavljevic, A. Despotovic, D. Bokonjic, J. Vladicic Masic, V. Janicijevic, S. Masic, and N. Milic. The flipped classroom in medical education: systematic review and meta-analysis. *J Med Internet Res*, 27:e60757, 2025.
- [20] X. Y. Shi, Q. Yin, Q. W. Wang, B. R. Lu, G. X. Li, S. H. Huang, et al. Is the flipped classroom more effective than the traditional classroom in clinical medical education: a systematic review and meta-analysis. *Front Educ*, 9, 2024. Article 1485540.
- [21] K. F. Hew and C. K. Lo. Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Med Educ*, 18:38, 2018.
- [22] M. K. Kim, S. M. Kim, O. Khera, and J. Getman. The experience of three flipped classrooms in an urban university: an exploration of design principles. *Internet High Educ.*, 22:37–50, 2014.
- [23] C. J. Ramnanan and L. D. Pound. Advances in medical education and practice: student perceptions of the flipped classroom. *Adv Med Educ Pract*, 8:63–73, 2017.